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The Taylor Rule, Wealth Effects and the Exchange Rate

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Abstract: In this study, we develop Taylor rule and Taylor rule-based exchange rate models that consider wealth effects as represented by both asset prices and asset wealth. Using data for Australia, Sweden, the UK and the US, we find that effects of asset prices and wealth on the Taylor rule vary depending on the country and on the form that wealth takes. Out-of-sample forecasting capacities of the wealth-augmented Taylor rule model and Taylor rule-based exchange rate model outperform conventional models and random walk theories for these countries.

Keywords: exchange rate, wealth effect, forecast

JEL F30, F37

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1. Introduction

In this study, we aim to analyze the relationship between monetary policies and asset market movements, which have become increasingly important for policy makers in numerous countries. The Japanese asset price bubble of the late 1980s and the 2008 international financial crisis serve as examples of rapid increases in asset prices following excessive monetary easing. This has facilitated a growing awareness among central banks of the importance of financial markets and wealth compositions when analyzing monetary policy instruments. During the 1990s, several economies experienced a sharp rise in household net wealth, and financial markets, including the foreign exchange, equity and housing markets, grew increasingly integrated. All of these changes have exposed the need for a stronger understanding of relationships between policy instruments and wealth compositions.

The importance of asset prices with respect to the conduct of monetary policies has been analyzed for a variety of reasons. For instance, asset prices can directly impact economic activity as a result of: (i) wealth effects on consumption; (ii) changes in investment through Tobin's Q and (iii) wealth effects on monetary and fiscal policy. In addition, excessive fluctuations in asset prices can seriously compromise financial stability levels. Moreover, as reported by Gilchrist and Leahy (2002), asset prices tend to incorporate information from a wide range of sources in a timely manner and may therefore act as useful proxies for the underlying state of the economy and for future economic activity.

Since inflation targeting was first introduced in the 1990s, the Taylor rule has become the main approach used to determine interest rates and monetary policies in general. Interest and exchange rates play a vital role in economic success, especially with respect to the conduct of monetary policy. Thus, it is important to understand which factors determine interest rate changes and how such factors interact with other asset markets.

Measures of wealth used in this study include both asset prices and measures of household wealth. As Case et al. (2005) suggest, both can have varying degrees of influence on the macro-economy. Following Castro and Sousa's (2012) approach, the relationship between monetary policies and asset markets is classified as a "price effect," whilst the importance of wealth compositions to the conduct of monetary policies is identified as a "quantity effect."

This study contributes to the existing literature by considering various wealth effects and by using the Taylor rule approach to determine policy interest rates, including those of equity and housing wealth. In turn, we develop insights into monetary policy responses to stock and housing market developments and into the extent to which these reactions differ across markets. Additionally, no studies have yet used the Taylor rule framework to investigate the relationship between asset prices and exchange rates, and this is the first study to use this approach to determine whether a subsequent improvement in the predictability of exchange rates occurs when such wealth effects are considered.

In estimating the Taylor-rule model, we use it as a means of forecasting the interest rate out-of-sample following Qin and Enders (2008). One of the most popular ways of comparing model performance levels relative to benchmark model performance levels (Molodstova and Papell, 2009) involves assessing out-of-sample forecasting capacities. A similar approach is adopted when one employs the wealth-augmented Taylor rule-based exchange rate model, which is also subsequently used to generate out-of-sample forecasts of the exchange rate. For both sets of forecasts, a variety of tests are used to evaluate the out-of-sample forecasting performance of asset-augmented models relative to standard models over the entire study period. Moreover, the Giacomini and Rossi (2010) fluctuation test is employed for the assessment of predictive performance stability levels.

This study shows that wealth effects serve as important determinants of interest rates, with asset wealth being more influential than asset prices. The addition of wealth effects to models has improved the forecasting capacities of the Taylor rule model and of corresponding exchange rate models. These results have important policy implications for central banks in terms of the need to include information on asset markets when determining monetary policies and when predicting future movements in major policy instruments.

Following this introduction, we include a literature review on the use of wealth effects in macroeconomic models, and in Section 3, we provide a description of the various models used. In Section 4, we describe the data used and our empirical approach, and the Taylor rule empirical results are then analyzed in Section 5. In Section 6, we assess our out-of-sample forecasting results using the Taylor rule-based exchange rate model. Finally, we offer some concluding comments.

2. Literature review

Although the literature that relates asset markets to Taylor rule-based exchange rate models is limited, Castro and Sousa (2012) suggest that there is a reasonable body of literature that relates assets markets to the Taylor rule (Semmler and Zhang, 2007) and to monetary policy in general (Friedman, 1988). Following the financial crisis of 2008, it has become increasingly evident that asset prices in general and housing prices in particular heavily affect the conduct of monetary policies. Before considering open economy factors, we first analyze the importance of asset markets to monetary policies and to the macroeconomy in general.

Most early works on the effects of asset prices on the macroeconomy have focused on the importance of wealth to the consumption function. A number of studies have assessed the impact of wealth effects in terms of asset prices on levels of consumption. For instance, Case et al. (2005) find that wealth effects, especially in terms of housing prices, serve as an important

determinant of consumption. Peltonen et al. (2012) obtain similar results using a panel data approach and find that wealth effects are significant in 14 emerging economies, though the relative importance of housing and financial wealth varies across these countries. Jawadi et al. (2014) find asymmetry and time-varying relationships between wealth and consumption in the UK and U.S., though less evidence of such relationships is found for the Eurozone area. Jawadi and Sousa (2014) also identify wealth effects on the consumption function, with relationships varying across consumption growth levels. Other studies that have found evidence of a relationship between wealth and consumption include Sousa (2010a) and Afonso and Sousa (2011a).

A number of studies have also highlighted the importance of wealth effects to fiscal policies, including Afonso and Sousa (2011b, 2012), who reveal significant interactions between fiscal policies, stock prices and housing prices. Agnello et al. (2012), Agnello et al. (2015) and Agnello and Sousa (2013) highlight the importance of asset wealth and asset prices to fiscal policy rules and evidence of countercyclical fiscal policies with respect to wealth within a non-linear framework. A number of studies, including Armada et al. (2015) and Sousa (2015), have also stressed the importance of wealth to the risk premium. In particular, these authors find that when wealth-to-income ratios change, reactions occur in both risk premiums on equities and in government bonds.

The importance of monetary policies to the performance of the economy and to its relationship with financial markets underscores the relevance of considering asset prices in the Taylor rule model. Studies such as Sousa (2010b, 2014) and Castro and Sousa (2012) show that monetary policy changes produce strong wealth effects, facilitating quick adjustments in financial wealth alongside more gradual changes in housing wealth. Mallick and Sousa (2012) also find that for a sample of emerging economies, wealth serves an important component of the transmission mechanism.

There is also an extensive body of literature on the importance of asset prices to exchange rate determination, and to equity in particular. These studies include Solnik (1987), who assesses the relationship between exchange rates and equity markets, and Smith (1992), who develops a portfolio balance model of the exchange rate that includes stock prices. In addition, Granger et al. (2000) analyze causal relationships between exchange rates and stock prices during the East Asian financial crisis. Overall, the results of these studies show that changes in stock prices have significant effects on the exchange rate, though in the models employed, housing has not typically been used as a wealth effect thus far.

This study builds on this literature by adding wealth effects to the Taylor rule framework. First, we estimate the Taylor rule model using stock prices, housing prices and their wealth equivalents for the U.S., the UK, Australia and Sweden. Second, we use this model to carry out out-of-sample interest rate forecasting. Finally, we use the same Taylor rule model as the basis for an exchange rate model, thus building on recent work in this area by adding wealth effects into the model. This approach is solely used for out-of-sample forecasting and is found to improve the model without wealth effects.

3. The Taylor rule model

The relationship between the interest rate and macro-fundamentals stems from the central bank's approach to monetary policy. According to the Taylor rule (Taylor, 1993), the simplest approach to monetary policy involves setting the interest rate in response to changes in inflation and the output gap.

$$i_t^* = \pi_t + \delta(\pi_t - \pi_t^*) + \gamma y_t + r^* \quad (1)$$

where i_t^* is the target of the short-term nominal interest rate, π_t is the inflation rate, π_t^* is the target level of inflation, y_t is the output gap or percent deviation of actual real GDP from an estimate of its potential level, and r^* is the equilibrium level of the real interest rate. By

combining parameters π_t^* and r^* from equation (1) into one constant term $\mu = r^* - \delta\pi^*$, we can derive the following form of the Taylor rule:

$$i_t^* = \mu + \lambda\pi_t + \gamma y_t \quad (2)$$

where $\lambda = 1 + \delta$.

Later studies by Clarida et al. (1998) and Taylor (2001, 2002) have suggested that the original Taylor rule must be modified when examining small open economies by including the real exchange rate within the interest rate rule.¹ In this regard, we define our baseline specification of the monetary policy-maker interest rate as:

$$i_t^* = \mu + \lambda\pi_t + \gamma y_t + \phi q_t \quad (3)$$

where q_t is the real exchange rate.

In addition to using the above baseline specification, this study extends the model through the addition of variables that represent wealth effects and asset prices to the baseline equation following studies such as Semmler and Zhang (2007).

$$i_t^* = \mu + \lambda\pi_t + \gamma y_t + \phi q_t + \beta w_t \quad (4)$$

where w_t is a vector of additional variables that represents wealth effects or asset prices. Another specification considered was the inertial and non-inertial hypothesis on the conduct of monetary policies, whereby a lagged interest rate is typically included in the Taylor rule model to account for central bank inertia and smooth interest rate adjustment to its target value. As a result, the actual observable interest rate i_t partially adjusts towards the target with a degree of inertia as follows:

$$i_t = (1 - \rho)i_t^* + \rho i_{t-1} + v_t \quad (5)$$

¹ Central banks in small open economies often set exchange rate targets to ensure PPP holds in the long run.

where ρ denotes the degree of interest rate smoothing and where v_t is the error term, which is also referred to as the interest rate smoothing shock value. Substituting (4) into (5) generates the following equation for the actual short-term interest rate:

$$i_t = (1 - \rho)(\mu + \lambda\pi_t + \gamma y_t + \beta w_t + \phi q_t) + \rho i_{t-1} + v_t \quad (6)$$

Equation (6) is treated as the interest rate reaction function of the foreign country in the subsequent exchange rate models, whilst the monetary policy reaction function for the U.S. is the same as that in equation (6), though $\phi = 0$.

In practice, to proceed with our estimation of equation (6), we consider the general form of the model as follows:

$$i_t = \alpha_m + \phi_m X_{m,t} + \eta_{m,t+1} \quad (7)$$

where subscript m represents the specific model that is being estimated and where i_t is the desired interest rate. $X_{m,t}$ is a vector that contains the economic variables used in the various models m . Specifications considered in this study include:

$$\text{Model 1: } X_{1,t} \equiv [\pi_t \ y_t \ \tilde{q}_t]$$

$$\text{Model 2: } X_{2,t} \equiv [\pi_t \ y_t \ \tilde{q}_t \ P_{stock} \ P_{house}]$$

$$\text{Model 3: } X_{3,t} \equiv [\pi_t \ y_t \ \tilde{q}_t \ fw \ hw]$$

$$\text{Model 4: } X_{4,t} \equiv [\pi_t \ y_t \ \tilde{q}_t \ i_{t-1}]$$

$$\text{Model 5: } X_{5,t} \equiv [\pi_t \ y_t \ \tilde{q}_t \ i_{t-1} \ P_{stock} \ P_{house}]$$

$$\text{Model 6: } X_{6,t} \equiv [\pi_t \ y_t \ \tilde{q}_t \ i_{t-1} \ fw \ hw]$$

where P_{stock} and P_{house} are stock and housing prices, respectively, and where fw and hw denote financial wealth and housing wealth, respectively. The generalized Taylor rule (7) includes a number of nested equations. For example, Model 1 is nested in Models 2 and 3, and Model 4 is nested in Models 5 and 6.

The new vector of parameters in (7) is related to the former in (6) as follows: $\alpha_m = (1 - \rho)\mu$, $\phi_m = [(1 - \rho)\lambda, (1 - \rho)\gamma, (1 - \rho)\phi, (1 - \rho)\beta, \rho]$. Therefore, based on estimates of the parameters obtained from (7), we can recover the implied estimates of $\mu, \lambda, \gamma, \phi$ and β and their respective standard errors using the delta method (see Ver Hoef, 2012).

4. Data

We include the following countries in this study: the UK, Australia, Sweden and the USA. All of these countries have strong housing markets and thus a plentiful supply of quarterly housing price data from the 1970s. Unlike numerous other countries, they also present high levels of home ownership and mortgage debt, resulting in the generation of a potentially strong relationship between housing markets, monetary policies and the broader economy. Moreover, the first three countries are relatively small, thus facilitating the construction of our Taylor rule-based exchange rate model. In addition, all of the countries examined have strong and highly liquid financial markets.

We used quarterly data for 1979:Q1 to 2008:Q4 for our estimations and forecasts. All variables except for the interest rate are calculated using natural logarithms.² As in other studies, stock and housing prices are used to represent asset prices, with financial and housing wealth used to account for asset wealth. A detailed description of these data can be found in Appendix A.

All of the variables used, with the exception of the financial variables, were obtained from *Thomson DataStream*. We used the CPI to measure price levels and, following Taylor

² While other studies have used a percentage change version of inflation, we followed Molodstova and Papell (2009) and used the logged difference of CPI as a measure of inflation. The output gap is constructed as a percent deviation of log GDP from its trend.

(1993), inflation levels were measured as the difference in the CPI logarithm over the previous four quarters. Money market rates are used as a measure of short-term interest rates. The nominal exchange rate is defined as the U.S. dollar price of foreign currency and is taken as the end-of-month exchange rate. The real foreign/U.S. exchange rate is calculated as the percentage deviation of the nominal exchange rate from the target defined by PPP (i.e., $\tilde{q}_t = s_t - (p_t - p_t^*)$, where p_t and p_t^* are natural logarithms for U.S. and foreign price levels, respectively, as measured by respective CPI levels.

Orphanides (2001) stressed the importance of using real time data when conducting monetary policy analyses, especially when using output gap measures. As real output data are revised routinely, output gap estimates must similarly be revised using both actual and potential output levels. Real-time data are based on vintages of data that are available to researchers at each point in time (i.e., before data revisions are applied). As real-time data are only available for the USA among the countries studied, we followed Molodtsova and Papell (2009) and used quasi-real time data when measuring the output gap.³ In this case, current vintage data were used, trends at period t were calculated using observations 1 to $t - 1$. Orphanides and van Norden (2002) identified imprecise output gap estimates made during Taylor rule implementation and concluded that policy reaction functions estimated with final data may produce misleading results on how policy makers react to information available to them in real time. Moreover, these authors showed that Taylor rule estimates based on quasi-real time output measures provide more accurate descriptions of policies than Taylor rules based on revised data. Studies by Molodtsova et al. (2008), among others, have highlighted the importance of real-time data use in Taylor rule-based exchange rate forecasting, and stronger

³ Though the data include revisions, trends do not use ex-post observations.

exchange rate forecasting capacities have been found among models that use quasi-real time data compared to those that use fully revised data.⁴

For our interest rate and exchange rate studies, real GDP data were used to make output gap estimates. To construct the output gap, a trend was estimated based on quasi-real time data. For the first vintage 1979:Q1, trends were determined using data for 1975:Q1 to 1978:Q4. For each subsequent vintage, we updated trends by one quarter. For example, the output gap for 1980:1 is the last deviation from a trend calculated for 1975:Q1 to 1979:Q4.

The three leading detrending methods include the following: the linear, quadratic and Hodrick-Prescott (1997) (HP) filter methods. Results presented by Nikolsko-Rzhevskyy and Papell (2012) and Nikolsko-Rzhevskyy et al. (2014) have already ruled out real-time linear detrending methods as appropriate tools for constructing output gaps. However, questions regarding real-time quadratic and HP detrended gap usage require further analysis. For this reason, we compare the two detrending methods, the HP filter and the quadratic detrending approach with quasi-real time output gaps as shown in Figures 1 to 4.

The quadratic detrended approach was preferred to the HP filter due to the former's following empirical observation and methodological shortcomings. When using Okun's Law as a benchmark, we generally found our results to favor the quadratic detrended output gap. This is consistent with Nikolsko-Rzhevskyy and Papell (2012) and Nikolsko-Rzhevskyy et al. (2014).⁵ Additional support derives from the construction of the HP filter itself, which presents

⁴ The model estimation and forecasting results based on revised data are available upon request. These results are similar to those of Molodstova et al. (2008) and Molodstova and Papell (2009). This was because we found less evidence of exchange rate forecasting capacities using the revised data.

⁵ In Nikolsko-Rzhevskyy and Papell (2012) and Nikolsko-Rzhevskyy et al. (2014), Okun's Law was used as a benchmark to determine the appropriate real-time output gap measure. Focusing on U.S. peak unemployment levels associated with the recessions of the 1970s and 1980s, the constructed "rule-of-thumb" output gaps for Q1

end-of-sample problems when used to estimate the output gap (Chagny and Döpke, 2001). The HP filter is a symmetric filter, thus leading to the production of biased results at both ends of the sample. As we used semi-real-time data, the HP filter was applied to each quasi-vintage dataset, and the very last observation was recorded at the very end of the vintage each time. This in turn generated a series composed entirely of low-quality estimates. Baxter and King (1999) show that employing the HP filter requires the use of additional data to ensure that the actual output gap generated makes sense. In addition, the HP filter was created long after the sample began. Therefore, based on all the above results, the quadratic detrended output gap was used for the remainder of the analysis.⁶

5. Interest rate estimation and forecasting using the Taylor rule model

5.1. Taylor rule model estimation

This section examines in-sample estimates of six specifications of the Taylor rule for the entire sample period of 1979:Q1 to 2008Q4. The models were estimated using Dynamic Ordinary Least Squares (DOLS), which corrects for independent variable endogeneity by including leads and lags of the first regressor differences and for serially correlated errors using a GLS procedure.⁷ The number of leads and lags used in the estimation was determined according to the Akaike information criterion.

The estimation results are listed in Tables 1, 2, 3 and 4, where we find that the inclusion of wealth effects improves the performance of Taylor rule models for certain countries and

were calculated as -10.5%. Compared to our calculations of real-time quadratic and HP gaps of -6.25% and -4.31%, respectively, Okun's Law gap is more similar to the quadratic gap than to the HP gap.

⁶ We would like to thank a referee for highlighting these facets of the HP filter.

⁷ The tables of Taylor rule model results exclude lead and lag values for the sake of brevity; the full results can be obtained from the authors upon request.

specifications. As shown in other studies, we find evidence of interest rate inertia and of the importance of inflation and the output gap to the determination of an interest rate policy. The inflation effect and output gap vary in importance depending on the model specification, as has been shown in other studies (e.g., Qin and Enders, 2008).

The “Taylor principle” suggests that for a stable monetary policy, the nominal interest rate must respond to a change in the inflation rate by more than unity. This denotes that a central bank must increase real interest rates to control inflation. For the standard Taylor rule used in Models 1 and 4, the estimated inflation coefficients are highly significant and are greater than unity for all of the countries studied. This reflects the Taylor principle, though when wealth effects are added to the model, λ becomes less than unity for some countries. However, as the wealth measures serve as additional measures of inflation, there is still reasonable evidence in support of the view that the countries studied have followed the Taylor principle for the period studied.

The results shown in Tables 1 to 4 highlight the varying impacts of wealth effects on monetary policies. The coefficient signs and significance of wealth effects differ across the countries. Other studies have also found the same result (e.g., Castro and Sousa, 2012). For the US model, housing price and wealth levels serve as the dominant wealth effects in determining interest rates. This reflects the results of Case et al. (2005), who found that for the U.S., housing wealth rather than financial wealth has the most significant effect on consumption. For the other three countries, the influence of both asset classes varies by country and model specification. In Sweden, the wealth measures outweigh asset prices in both smoothing and non-smoothing models. In Australia, the wealth measures again are more important than asset prices, though this is not a particularly robust result, as the effects become insignificant when interest rate smoothing is included. In the UK, the effects of asset prices and wealth on interest rates are not strong, and with smoothing such effects become insignificant.

One other key conclusion that we draw from these results pertains to the importance of including financial and housing wealth as separate determinants of interest rates. This conclusion has also been found in other studies (e.g., Castro and Sousa, 2012). For instance, depending on the country and model specification, housing and equity prices tend to have opposite effects on interest rates. This finding denotes that central banks struggle to stabilize equity and housing markets simultaneously. The finding also suggests that investors move funds between the two markets so that when monetary interventions stabilize one market, funds are moved to the more profitable market, which in turn is destabilized. The greater significance of the wealth measures compared to that of the asset prices suggests that central banks are more likely to react to shifts in wealth levels than to shifts in asset prices, possibly due to the importance of asset wealth to the broader macroeconomy, especially in terms of consumption. This also supports the view that wealth effects on price stability rather than on asset price stability are the main concern of central banks.

A number of policy implications arise from these results. First, they confirm the importance of wealth effects to macroeconomic models in general, as found previously by Case et al. (2005). This study showed that both equity and housing wealth significantly affect consumption — although housing tends to dominate, as we have also found. This is not surprising given that all of the countries examined in this study have strong private sector housing markets, where individual housing wealth levels tend to exceed stock market wealth levels. This suggests that financial authorities may use a measure of wealth either directly or indirectly in interest rate reaction functions, and particularly one relating to housing wealth. However, our results indicate that the nature of the relationship between monetary policies and asset markets varies across countries, and so the form of wealth that authorities monitor depends on a country's individual circumstances. Again, this finding confirms results found in other similar studies (e.g., Castro and Sousa, 2012).

5.2. Interest rate forecasting using the Taylor rule model

This section examines the extent to which wealth effects enhance the out-of-sample forecasting performance of interest rates as implied by the Taylor rule. We assume that the central bank uses all relevant, available, and current information to make forecasts concerning inflation and the output gap. Therefore, a forward-looking Taylor rule with interest rate smoothing is used as a benchmark:

$$i_t = (1 - \rho)(\mu + \lambda E(\pi_t | \Omega_t) + \gamma E(y_t | \Omega_t) + \phi q_t) + \rho i_{t-1} + v_t \quad (8)$$

Here, the information set Ω_t contains all past realizations of the output gap and of inflation up to current levels.

We follow the same principal as that presented by Qin and Enders (2008) by first constructing quasi-real time forecasts of the output gap and of inflation. K -step-ahead forecasts are then generated using the chain rule of forecasting. This involves substituting the $k - 1$ step-ahead forecast for the interest rate, i , to obtain out-of-sample forecasts. We used rolling regressions with a moving window of 40 quarters (10 years) to produce one-quarter-ahead forecasts. For the period of 1989Q1 to 2008Q4, we generate the forecast interest rate, and this forecast is then compared to the actual data, where the initial estimation period extends from 1979Q1 to 1988Q4.

When measuring the forecast performance of a model, the mean square prediction error (MSPE) is the criterion most commonly used to compare the forecasting accuracy of a set of models. In the case of non-nested models, Diebold and Mariano (1995) and West (1996) MSE-t tests (DMW test) are often used to evaluate forecasting performance levels. McCracken (2007) more recently developed an out-of-sample F-type test of equal MSE. Both tests are

effective at evaluating the forecasting performance of non-nested models. However, for nested models, which are used in this study, test properties are likely to differ.⁸

As we compare a set of nested models, a number of forecast performance evaluation criteria that are appropriate for use in nested models are applied. These include the CW test, Clark and McCracken's (2001) encompassing test and the modified Diebold and Mariano (1995) encompassing test, proposed initially by Harvey et al. (1998).⁹ Moreover, the fluctuation test, as proposed by Giacomini and Rossi (2010), is used to investigate possible fluctuations in the relative predictive capacities of the forecast models. Unlike the CW and other tests, which select the model with the best overall forecasting performance, this test focuses on the entire time path of relative model performance by plotting the standardized sample path of the relative measure of local performance (the difference in MSFEs) together with corresponding critical values, denoting that, if crossed, one of the models will have outperformed its competitor at some point.

Table 5 presents the one-quarter-ahead out-of-sample forecasts for the interest rate based on the wealth-augmented Taylor rule with the forward-looking Taylor rule model used

⁸ Clark and McCracken (2001, 2005) and McCracken (2007) show that the distribution of test statistics is not normally distributed for a pair of forecasts derived from a nested model. Clark and McCracken (2012) further show that both MSE-t and MSE-F distributions are non-standard when forecasts are nested under the null. Therefore, the use of standard normal critical values will result in the execution of very poorly sized tests with too few rejections of the null.

⁹ It is worth noting that DMW and CW tests do not necessarily imply the same results. CW tests examine whether a regression coefficient is zero and not whether the sample MSPE of a model-based forecast is smaller than the sample MSPE of a benchmark forecast. Generally speaking, if the CW statistic is significant, this denotes that wealth does belong to the Taylor rule, though this cannot necessarily be interpreted as evidence of forecasting capacity (i.e., enhancing the Taylor rule to make a profitable trade based on a forecast). The non-nested test results are available from the authors upon request.

as the benchmark. The overall results present evidence of short-term predictability, especially for the UK, the U.S. and Sweden, with both asset prices and asset wealth measures outperforming the simple Taylor rule model without wealth effects. Therefore, we can conclude that Taylor rules with wealth effects improve the standard Taylor rule in terms of out-of-sample predictability.

Figure 5 shows the results of the Giacomini and Rossi (2010) fluctuation tests that use the Taylor rule model, which assesses predictive stability levels over time. Though the standard performance forecasting test presents evidence of higher predictive capacities of wealth effect models overall, this does not guarantee the test's robustness at each point in time. As values of the statistics do not always fall below critical values, we reject the null hypothesis of equal predictive capacity at each point in time, though this rejection is limited to short periods corresponding to excessive economic volatility levels (e.g., the Swedish banking crisis of the early 1990s), which directly impact monetary policies.

6. Out-of-sample Taylor rule-based exchange rate predictability

6.1. An exchange rate model based on Taylor rule fundamentals

Out-of-sample forecasting is often used to identify the optimal model from a set of alternative exchange rate specifications. In this section, we use wealth-augmented Taylor rule models to develop three wealth augmented models of the USD/foreign nominal exchange rate. The first specification assumes that both U.S. and foreign monetary authorities determine their interest rates based on a Taylor rule, where the nominal interest rate responds to inflation, the output gap, the real exchange rate and the lagged interest rate. The second and third specifications include a vector of additional variables, w_t , which represent asset prices and wealth composition levels, respectively.

To determine the out-of-sample forecasting capacities of these models, we use a similar approach as that of Molodtsova and Papell (2009). By subtracting the Taylor rule model for the foreign country from that for the USA., an exchange rate forecasting equation with Taylor rule fundamentals can be derived. Let \sim denote variables for the foreign country. By subtracting the Taylor rule equation for the foreign country from that of the domestic country — in this case, the USA — we obtain:

$$\begin{aligned} i_t - \tilde{i}_t = & \psi + (\psi_{u\pi}\pi_t - \psi_{f\pi}\tilde{\pi}_t) + (\psi_{uy}y_t - \psi_{fy}\tilde{y}_t) + (\psi_{uw}w_t \\ & - \psi_{fw}\tilde{w}_t) - \psi_q\tilde{q}_t + \rho_u i_{t-1} - \rho_f \tilde{i}_{t-1} + \eta_t \end{aligned} \quad (9)$$

where the subscripts u and f represent the USA and the foreign country, respectively. ψ is a constant; $\psi_\pi = \lambda(1 - \rho)$, $\psi_y = \gamma(1 - \rho)$ and $\psi_w = \beta(1 - \rho)$ for both countries; and $\psi_q = \phi(1 - \rho)$ for the foreign country.

The simplest and most direct way to determine the exchange rate equation involves assuming that the expected rate of exchange rate depreciation is proportional to the interest rate differential or to uncovered interest parity (UIP):

$$E(\Delta s_{t+1}) = \beta(i_t - \tilde{i}_t) \quad (10)$$

where Δs_{t+1} is the logarithmic difference of the nominal exchange rate, which is specified as the price of the home currency in relation to the foreign currency, and where E denotes the expectations operator. In substituting (9) into (10), we obtain the following standard Taylor rule exchange rate forecasting model presented in Molodstova and Papell (2009):

$$\begin{aligned} \Delta s_{t+1} = & \delta + \delta_{u\pi}\pi_t - \delta_{f\pi}\tilde{\pi}_t + \delta_{uy}y_t - \delta_{fy}\tilde{y}_t + \delta_{uw}w_t - \delta_{fw}\tilde{w}_t \\ & - \delta_q\tilde{q}_t + \delta_{ui}i_{t-1} - \delta_{fi}\tilde{i}_{t-1} + \eta_t \end{aligned} \quad (11)$$

where s_t is the natural log of the U.S. nominal exchange rate, which is defined as the U.S. dollar per unit of foreign currency. Thus, an increase in s_t implies a depreciation of the U.S. dollar. The above model is then augmented with asset prices and wealth levels as in Taylor rule models (1) to (6) described in Section 3.

Based on Molodtsova and Papell (2009) and Molodtsova and Ince (2008), and given a lack of empirical support for UIP, there is no reason to believe that coefficients in equation (11) will match coefficients implied by the estimated Taylor rule exchange rate model.¹⁰ As we do not know the extent to which changes in the interest rate differential affect the exchange rate, we estimate our forecasting equations without imposing any restrictions on the coefficient signs and magnitudes.

6.2. Tests of equal predictability

The benchmark model we use in this section accounts for corresponding models without wealth effects. These models offer useful information on whether wealth effects improve forecasting performance levels.¹¹

The benchmark: the Taylor rule exchange rate model without wealth effects.

$$\begin{aligned} \Delta s_{t+1} = & \delta + \delta_{u\pi}\pi_t - \delta_{f\pi}\tilde{\pi}_t + \delta_{uy}y_t - \delta_{fy}\tilde{y}_t - \delta_q\tilde{q}_t + \delta_{ui}i_{t-1} \\ & - \delta_{fi}\tilde{i}_{t-1} + \eta_t \end{aligned} \quad (11)$$

Using the same approach as that used in our earlier forecast of interest rates with the wealth-augmented Taylor rule model, rolling regressions incorporate a moving window of 40

¹⁰ Kearns and Manners (2006) suggest that while UIP has been argued by many to be an empirical failure (e.g., Chinn, 2006), it may work reasonably well in a small economy, such as in the three economies used here. Changes in interest rates in small economies are unlikely to affect foreign interest rates and thus affect the exchange rate. Moreover, UIP relates expected changes in exchange rates to interest differentials, which have been shown to be important and useful transmission channels that relate exchange rate changes endogenously to monetary policies (Molodtsova and Papell, 2009).

¹¹ One standard benchmark is the random walk with no drift. As it is an established empirical fact that the Taylor rule model outperforms the random walk with no drift (e.g., Molodtsova and Papell, 2009), these results are not presented here but are available upon request.

quarters (10 years). The forecasts are conducted for the period of 1989Q1 to 2008Q4, with the initial estimation period spanning from 1979Q1 to 1988Q4.

Tables 6, 7 and 8 present the results of out-of-sample forecasts for the Taylor rule-based exchange rate models. Overall, the results show clear forecasting improvements for the models with wealth effects. At the one-quarter horizon, models with wealth effects dominate those without effects for all three exchange rates.

Specifications that incorporate asset prices include Models 2 and 5, while Models 3 and 6 include wealth effects. As with our forecasts of the interest rate, the two wealth measures do not differ considerably in terms of forecasting performance. The only exception is Australia, where asset price specifications outperform the asset wealth models. A possible explanation for this exception may relate to the fact that Australia is a commodity-based economy, and thus changes in commodity prices influence the country's exchange rate to a greater extent than they do in non-resource rich economies, as described in Chen and Rogoff (2003). Changes in commodity prices are likely to be reflected in faster shifts to asset prices than to asset wealth.

Figure 6 presents fluctuation test results of the exchange rate forecasts based on the asset price models. The wealth composition model statistical values are similar and are therefore not reported. We conclude that the Taylor rule-based exchange rate models with wealth effects do not uniformly outperform the standard Taylor rule exchange rate models in exchange rate forecasting, though once again, this failure is limited to very short periods of excessive volatility in the exchange rate (e.g., the European Exchange Rate Mechanism (ERM) crisis in the UK in September of 1992).

7. Conclusions

The primary aim of this paper was to explore the relationship between Taylor rule-implied monetary policy interest rates and wealth effects. Based on a selection of countries

with strong housing and financial markets, we have estimated a set of monetary policy reaction functions to determine how central banks respond to wealth composition and asset prices. Empirical evidence derived from our in-sample and out-of-sample analyses allude to the following main conclusions. Including wealth effects improves the performance of the Taylor rule model in terms of in-sample performance and out-of-sample forecasting. However, estimates of the wealth-augmented Taylor rule models vary across countries depending on whether housing or stock prices measure wealth effects. As shown in other similar studies, housing tends to have the most significant effect, especially in the US. In addition, the results are sensitive to wealth forms, models based on asset wealth generating superior results than those based on asset prices.

The second purpose of this paper was to investigate how wealth effects affect out-of-sample nominal exchange rate predictability levels. Such exchange rates are derived from Taylor rule models that incorporate Taylor rule fundamentals and various representations of wealth effects. Our out-of-sample forecasting results highlight the importance of the wealth effect to the determination of exchange rates. That is, forecasts of the wealth-augmented Taylor type exchange rate model tend to outperform those of the standard Taylor type exchange rate model, which excludes wealth effects. Overall, the inclusion of wealth effects in this model provides evidence of their importance in determining exchange rates, and this has been found previously in other specifications of wealth-augmented exchange rate models.

The policy implications of these results highlight the need for a stronger emphasis on the role of wealth effects in determining monetary policies, though these effects vary depending on wealth measures and across different countries. When assessing and predicting movements using the main monetary instruments, the use of a wealth measure significantly improves the accuracy of predictions, facilitating more effective economic management by authorities.

Future studies may explore the relevance of alternative measures of wealth to these models (e.g., measures of combined financial wealth) as data become increasingly available.

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Table 1. Estimates of the Taylor rule model for the UK

| UK | | | | | | |
|----------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <i>Parameter</i> | <i>Model 1</i> | <i>Model 2</i> | <i>Model 3</i> | <i>Model 4</i> | <i>Model 5</i> | <i>Model 6</i> |
| μ | 8.939** | 13.379** | 37.083* | 9.102* | 5.951 | 19.559 |
| λ | 1.124** | 1.038** | 0.311 | 1.282** | 1.355** | 0.992* |
| γ | 0.586** | 0.698** | 1.482* | 0.983** | 0.805** | 1.089** |
| ϕ | -9.606** | -7.289** | -5.081 | -11.305 | -9.927 | -13.208 |
| ρ | | | | 0.823 | 0.713 | 0.764** |
| β_{stock} | | 0.536 | | | 1.178 | |
| β_{house} | | -2.088** | | | -1.453 | |
| β_{fw} | | | -3.222* | | | -1.195 |
| β_{hw} | | | -0.650 | | | 0.008 |
| <i>Adj. R</i> ² | 0.761 | 0.856 | 0.771 | 0.939 | 0.939 | 0.939 |

Notes: This table presents estimates of the Taylor rule based on equation (6), where μ , λ , γ , ϕ and β denote estimated coefficients of the variables for the entire sample period; respective standard errors are recovered from the estimated general form using the delta method. The models are estimated using the Dynamic OLS estimator, where standard errors have been Newey-West corrected. Along with fundamentals in levels, the first difference and the first differences with up to two period lags were considered in the DOLS models. Here, due to space restrictions, only coefficients of level fundamentals are reported. ** and * denote significance at the 1% and 5% levels, respectively.

Table 2. Estimates of the Taylor rule model for Sweden

| Sweden | | | | | | |
|---------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <i>Parameter</i> | <i>Model 1</i> | <i>Model 2</i> | <i>Model 3</i> | <i>Model 4</i> | <i>Model 5</i> | <i>Model 6</i> |
| μ | 18.879** | 40.982** | 37.596** | 13.051 | 38.552** | 35.501** |
| λ | 1.010** | 0.479** | 0.057 | 1.127** | 0.569* | 0.048 |
| γ | -0.022 | 0.278** | 0.064 | 0.045 | 0.476* | 0.067 |
| ϕ | 7.964** | 3.893** | 0.394 | 5.268 | 5.968* | 0.428 |
| ρ | | | | 0.843** | 0.752** | 0.565** |
| β_{stock} | | 0.665 | | | 0.173 | |
| β_{house} | | -6.020** | | | -4.056 | |
| β_{fw} | | | -5.220** | | | -5.480** |
| β_{hw} | | | 2.992** | | | 3.393** |
| <i>Adj. R²</i> | 0.861 | 0.904 | 0.937 | 0.951 | 0.960 | 0.958 |

Notes: This table presents estimates of the Taylor rule based on equation (6), where μ , λ , γ , ϕ and β denote the estimated coefficients of the variables for the entire sample period; respective standard errors are recovered from the estimated general form using the delta method. The models are estimated using the Dynamic OLS estimator, where standard errors have been Newey-West corrected. Along with fundamentals in levels, the first difference and the first differences with up to one period lag were considered. Here, due to space restrictions, only coefficients of level fundamentals are reported. ** and * denote significance at the 1% and 5% levels, respectively.

Table 3. Estimates of the Taylor Rule model for Australia

| Australia | | | | | | |
|----------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <i>Parameter</i> | <i>Model 1</i> | <i>Model 2</i> | <i>Model 3</i> | <i>Model 4</i> | <i>Model 5</i> | <i>Model 6</i> |
| μ | 4.866** | 21.209** | 0.860 | 7.212* | 51.274* | 18.883 |
| λ | 1.140** | 0.824** | 0.988** | 1.230** | 0.752 | 0.829 |
| γ | 0.281 | 0.582** | 0.362* | 1.115* | 1.291* | 0.712 |
| ϕ | 3.483 | 4.933* | 5.556** | 11.681 | 15.017* | 9.243 |
| ρ | | | | 0.887** | 0.883** | 0.889** |
| β_{stock} | | -1.353 | | | -9.880 | |
| β_{house} | | -1.072 | | | 8.393 | |
| β_{fw} | | | 10.958** | | | -2.973 |
| β_{hw} | | | -9.308** | | | 0.811 |
| <i>Adj. R</i> ² | 0.675 | 0.781 | 0.757 | 0.945 | 0.955 | 0.945 |

Notes: This table presents estimates of the Taylor rule based on equation (6), where μ , λ , γ , ϕ and β denote the estimated coefficients of the variables for the entire sample period; respective standard errors are recovered from the estimated general form using the delta method. The table shows coefficients of the variables for the entire sample period. Models are estimated using the Dynamic OLS estimator, where standard errors have been Newey-West corrected. Along with fundamentals in levels, the first difference and the first differences with up to one period lag were considered. Here, due to space restrictions, only coefficients of level fundamentals are reported. ** and * denote significance at the 1% and 5% levels, respectively.

Table 4. Estimates of the Taylor rule model for the USA

| U.S. | | | | | | |
|---------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| <i>Parameter</i> | <i>Model 1</i> | <i>Model 2</i> | <i>Model 3</i> | <i>Model 4</i> | <i>Model 5</i> | <i>Model 6</i> |
| μ | 1.059** | 23.927** | 32.017** | -1.935 | 9.004 | 12.541 |
| λ | 1.366** | 1.107** | 0.856** | 2.115** | 2.235** | 1.645** |
| γ | 0.061 | 0.396** | 0.317** | 0.360 | 0.329 | 0.459 |
| ρ | | | | 0.861** | 0.766** | 0.828 |
| β_{stock} | | 0.198 | | | 0.979 | |
| β_{house} | | -4.812** | | | -3.667 | |
| β_{fw} | | | 0.021 | | | 0.820 |
| β_{hw} | | | -3.393** | | | -2.506 |
| <i>Adj. R²</i> | 0.743 | 0.879 | 0.833 | 0.958 | 0.969 | 0.958 |

Notes: This table presents estimates of the Taylor rule based on equation (6), where μ , λ , γ , ϕ and β denote estimated coefficients of the variables for the entire sample period; respective standard errors are recovered from the estimated general form using the delta method. The table shows coefficients of the variables for the entire sample period. The models are estimated using the Dynamic OLS estimator, where standard errors have been Newey-West corrected. Along with fundamentals in levels, the first difference and the first differences with up to two period lags were considered. Here, due to space limitations, only coefficients of level fundamentals are reported. ** and * denote significance at the 1% and 5% levels, respectively.

Table 5. Tests for superior forecasting ability of the interest rate using the Taylor rule

| UK | | | | |
|-----------|-------------|-----------|--------------|--------------|
| | <i>MSPE</i> | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 4 | 0.670 | - | - | - |
| Model 5 | 0.644 | 1.528* | 27.900*** | 2.469*** |
| Model 6 | 0.599 | 1.641* | 16.058*** | 1.946** |
| Sweden | | | | |
| | <i>MSPE</i> | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 4 | 0.888 | - | - | - |
| Model 5 | 0.925 | 2.001** | 24.219*** | 2.824*** |
| Model 6 | 0.933 | 1.630* | 6.591*** | 1.071 |
| Australia | | | | |
| | <i>MSPE</i> | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 4 | 0.414 | - | - | - |
| Model 5 | 0.333 | 3.059** | 25.864*** | 3.429*** |
| Model 6 | 0.456 | 1.448* | 20.110*** | 2.339*** |
| US | | | | |
| | <i>MSPE</i> | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 4 | 0.396 | - | - | - |
| Model 5 | 0.433 | 1.549* | 30.838*** | 3.156*** |
| Model 6 | 0.402 | 2.502** | 39.462*** | 3.740*** |

Notes: Significance levels at 90%, 95%, and 99% are denoted by *,** and *** respectively.

The MSPE falls between respective Taylor rule model and actual interest rate values. The CW, ENC-F and ENC-t are test values relative to the benchmark Taylor rule without the wealth effects model (Model 4). For the CW statistics, the null hypothesis is rejected if the statistic is greater than +1.282 (for a one-sided 0.10 test) or +1.645 (for a one-sided 0.05 test). Critical

values of ENC-F and ENC-t were obtained from Clark and McCracken (2001) and McCracken (2004), respectively.

Table 6. Tests on the superior forecasting capacities of the UK/US exchange rate

| Benchmark: Model 1 | | | |
|--------------------|-----------|--------------|--------------|
| | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 2 | 2.218** | 25.518*** | 2.557*** |
| Model 3 | 2.016** | 13.717*** | 2.078** |
| Benchmark: Model 4 | | | |
| | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 5 | 2.149** | 18.126*** | 2.104** |
| Model 6 | 1.905** | 13.925*** | 2.228*** |

Note: CW, ENC-F and ENC-t are test values relative to the benchmark. Significance levels of 90%, 95%, and 99% are denoted by *,** and *** respectively. For the CW statistics, the null hypothesis is rejected if the statistic is greater than +1.282 (for one-sided 0.10 tests) or +1.645 (for one-sided 0.05 tests). Critical values of ENC-F and ENC-t were obtained from Clark and McCracken (2001) and McCracken (2004), respectively. Random walk MSPE: 0.00221.

Table 7. Tests on the superior forecasting capacities of the Swedish/US exchange rate

| Benchmark: Model 1 | | | |
|--------------------|-----------|--------------|--------------|
| | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 2 | 2.539** | 34.933*** | 2.470*** |
| Model 3 | 2.680** | 26.257*** | 2.978*** |
| Benchmark: Model 4 | | | |
| | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 5 | 2.509** | 34.816*** | 2.348*** |
| Model 6 | 2.622** | 16.269*** | 2.567*** |

Note: see notes for table 6.

Table 8. Tests on the superior forecasting capacities of the Australia/US exchange rate

| Benchmark: Model 1 | | | |
|--------------------|-----------|--------------|--------------|
| | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 2 | 2.255** | 17.626*** | 1.717** |
| Model 3 | 0.403 | 4.271* | 0.843 |
| Benchmark: Model 4 | | | |
| | <i>CW</i> | <i>ENC-F</i> | <i>ENC-t</i> |
| Model 5 | 1.876** | 18.117*** | 2.029** |
| Model 6 | 0.234 | 0.653 | 0.154 |

Note: see notes for table 6.

Appendix A: Wealth data

The UK:

Gross housing wealth is defined as the housing wealth of households and non-profit organizations. The United Kingdom National Accounts - The Blue Book is used as our data source. The data are measured in millions of pounds. Financial wealth is defined as the net financial wealth of households and non-profit organizations; these data are obtained from Table A64 of the UK Economic Accounts, measured in millions of pounds. Quarterly data were estimated by linear interpolation. Stock prices are the quarterly closing prices of the FTSE All Share Price Index. Housing prices were drawn from the Oxford Economic Indices.

Australia:

Net Financial Wealth: We use quarterly data for 1988:Q4 onward from the ABS Cat No 5232.0 and annual data of the RBA Occasional Paper No. 8 for data collected before this date. Household gross non-financial wealth: quarterly data for 1988:Q4 onward were drawn from the ABS Cat No 5232.0, and annual data of the RBA Occasional Paper No. 8 were used as data collected before this date. All data are measured in billions of Australian dollars. Quarterly data were estimated by linear interpolation. Stock prices are quarterly closing prices of the ASX All Ordinaries 1971. Housing prices were drawn from the Oxford Economic Indices.

Sweden:

Net household financial wealth data denote the difference between total household financial assets and total financial liabilities (both including NPISH) and are drawn from the FA (financial account) of the SCB. Gross housing wealth is the value of housing stock based on the tax assessment value of owned permanent and seasonal homes (SCB, 2004) multiplied by the purchase-price-coefficient (KB) of each type. Quarterly purchase-to-assessed value coefficients were available for only after 1998Q1. Quarterly data for before 1998 were estimated by linear interpolation. All data are measured in millions of Swedish krona. Stock

prices are the quarterly closing prices of the OMX Stockholm 30 and OMX Stockholm. Housing prices were drawn from the Oxford Economic Indices.

The US:

Financial wealth is defined as the sum of financial assets minus financial liabilities. Housing wealth is defined as the value of real estate held by households minus home mortgages. We use Table B.100 of the Federal Reserve System Board of Governors Flow of Funds Account as our data source. Data are quarterly, are measured in billions of dollars, and are expressed in logarithmic form. Stock prices are quarterly closing prices of the Standard & Poor 500 Composition Index. Housing prices were drawn from the Oxford Economic Indices.